

Design and Fabrication of Spur Gear Using Al6063+SiC Metal Matrix Composite

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Abstract: *Gears are the most essential and commonly utilised power transmission components. It is really essential to operate machines involving different weights and speeds. When a load is increased beyond a certain limit, gear teeth frequently fail. Composite materials, in comparison to other metallic gears, offer significantly better mechanical qualities, such as a higher strength-to-weight ratio, increased hardness, and hence a lower risk of failure. Al6063 and SiC were employed to build a metal matrix composite for spur gear production in this work. This study discovered that composite materials outperformed steel alloys and cast iron in terms of characteristics, and that composites can thus be utilised to replace metallic gears.*

Keywords: Al6063, casting, composite, metal matrix, spur gear

1. INTRODUCTION

In the present era, material development tends towards composite material due to its improved physical and mechanical properties, including superior strength to weight ratio. The aerospace and automobile industries require high specific modulus and low coefficient of thermal expansion, excellent wear, and corrosion-resistant materials. The researcher needs to develop materials that can meet most industry product development requirements.

Engineered or naturally occurring composite materials are made up of two or more elements with differing physical or chemical properties. Constituent materials are the individual materials that comprise composites. Matrix and reinforcement are the two types of component materials. Each type must have at least one piece. By maintaining the relative locations of the reinforcing components, the matrix material surrounds and supports them. The reinforcements increase the matrix qualities by imparting their specific mechanical and physical capabilities. In combination with low density, polymer composite materials provide great strength and stiffness. These characteristics are useful in constructions that use non-renewable energy to carry products and people. It reduces weight while maintaining transit capacity, lowering overall costs and fuel usage.

Composite spur gears were created and tested at NASA's Glenn Research Center. The composite material served as the web of the gear, connecting the gear teeth to a metallic hub for attachment to the torque-applying shaft. The inner and outer hexagonal parts of an all-metal aircraft class spur gear were only attached to the composite web. The Hybrid Gear was compared to an all-steel gear as well as another Hybrid Gear. Due to the composite to metal production procedure used, the gears' concentricity was lowered from their initial high precision value. More than 300 million cycles at 10000 rpm and 553 in-lb torque were completed by the hybrid gears[1].

Pawar et al. [2] investigated a composite made by combining silicon carbide with aluminium metal in the following mass ratios: 2.5 percent, 5%, 7.5 percent, and 10%. The composite was made via stir casting. Hardness and microstructure tests were performed as part of the mechanical testing. The results of the tests revealed that the produced composite is suitable for power transmission components such as gears that are subjected to constant loading. When the silicon carbide content of the material was increased, it improved the material's hardness and toughness. Composite materials, such as aluminium silicon carbide, are suitable for power transmission gears, according to the research.

The transmission efficiency of pure polyamide 6 (PA6) and clay contained polyamide nanocomposite (PNC) spur gears is reported by Kirupasankar et al. [3]. In this study, the frictional and hysteresis power losses were predicted using numerical simulations. The power loss during transmission was measured using in-house- built power absorption-type gear test equipment. It is reported on the influence of applied torque on the transmission efficiency of PA6 and PNC spur gears. The addition of nano clay particles enhances the stiffness of polyamide 6 and reduces its viscoelastic character. The effect of hysteresis and friction on gear tooth temperature substantially impacts tooth shape and, as a result, gear performance. Compared to pure polyamide gear, the improved mechanical qualities of polyamide nanocomposite gears result in greater power transfer efficiency.

Hu et al. [4] chose short carbon fibre reinforced nylon spur gear pairs and steel and unreinforced nylon spur gear pairs for study and comparison. A 3D finite element model was created to explore the multi-axial stress-strain characteristics of the gear tooth. The tooth roots, which are under a lot of stress and are prone to failure, have been intensively studied. Short carbon fibre reinforced nylon gear manufactured with carefully managed injection moulding methods can boost strength and performance, according to the modelling findings.

A new self-healing composite gear with 3.5w% microcapsules has little influence on composite gears' static bending strength [5].

Spur gears are the simplest and most extensively utilised in power transmission, according to the literature. Machines have been needed to work at various weights and speeds in recent years. When a load is increased beyond a certain limit, gear teeth frequently fail. As a result, alternative materials for gear production must be investigated. As a result, the current research is an attempt to look at alternative metal composite materials. Spur gears are the simplest and most extensively utilised in power transmission, according to the literature. Machines have been needed to work at various weights and speeds in recent years. When a load is increased beyond a certain limit, gear teeth frequently fail. As a result, alternative materials for gear production must be investigated. As a result, the current research is an attempt to look at alternative metal composite materials.

2. DEVELOPMENT OF COMPOSITE

2.1 Selection of raw materials

For the Al6063+SiC Metal Matrix Composite, three primary materials were utilized. The first material is Al 6063 aluminium alloy, with magnesium and silicon as the alloying elements. Al6063 is the most common alloy which is used for aluminium extrusion. The second material which was utilized was Silicon Carbide. It is an important material for sandpapers, grinding wheels, and cutting tools. The casting of material by reinforcement is complex due to its density difference. The Borax powder helps in increasing weldability and makes it easy to cast. For the casting purpose, the Al6063, SiC, and Borax were used in the weight of 3500 gm, 250 gm, and 50 gm, respectively. The materials used for casting are shown in Figure 1.

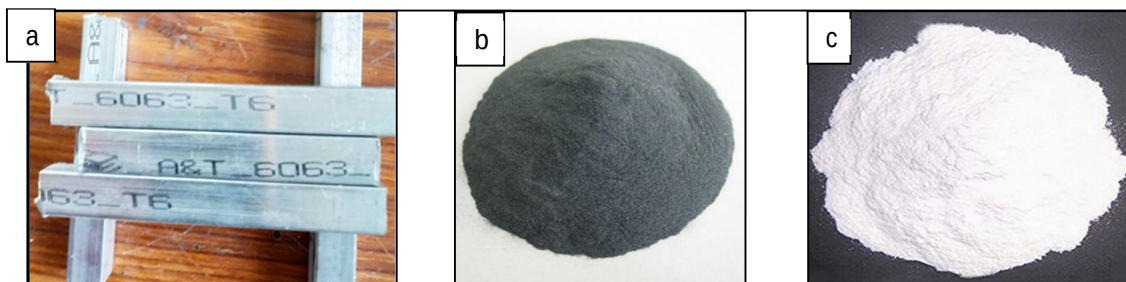


Fig. 1. The casting material used: (a) Al6063, (b) SiC powder (c) Borax powder

2.2 Material Casting Process

For the casting process, the material size of Al was reduced to 5cm using a hacksaw to dip into the crucible [refer to Figure 1]. To complete the casting process, the Al6063 is heated in a crucible in a furnace. Stir casting was used to make the aluminum-based SiC particulate metal matrix composite. Figure 2 depicts the stir casting procedure. The aluminium and silicon carbide were mixed in proportions of 95 percent and 5%, 92.5 percent and 7.5 percent, and 90 percent and 10%. Aluminium ingots have been utilised as the raw material for composite preparation. These metal ingots were cleaned and melted in graphite crucibles at a temperature of 750°C. Melting took place in a three-phase electrical resistance furnace with a temperature-controlled apparatus. A total of 750-1000g of alloy was used in the melting process. Before adding the SiC particles, they were warmed to roughly 500°C and then constantly mixed with a mechanical stirrer. For 5 to 8 minutes, the mixture was stirred. Borax was added in modest amounts during stirring to enhance the wettability of SiC particles. The molten material of different compositions was poured into blocking of 14×7×2cm. The detailed composition of the composite is shown in Table 1.

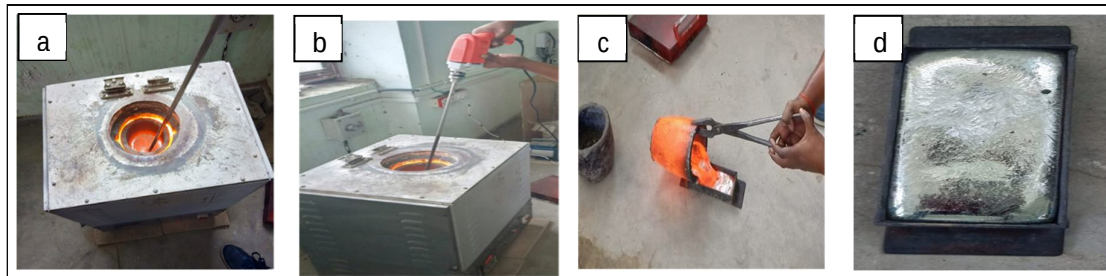


Fig. 2. Material casting processes (a) heating, (b) stirring, (c) pouring (d) solidification

Table 1. Composition of composites

S. No.	Al (%)	SiC (%)	Borax (%)	Al wt. for casting	SiC wt. for casting	Borax wt. for casting
1	95 %	5%	1%	720g	37.5g	1g
2	92.5 %	7.5%	1%	700g	56.25g	1g
3	90 %	10%	1%	675g	75g	1g
4	90%	10%	1%	900g	100g	1g

3. MECHANICAL TESTING

3.1 Preparation of the samples

The test samples from the composites of different compositions were prepared as per the ASTM standard. The prepared specimens for the impact and hardness test are shown in Figure 3.

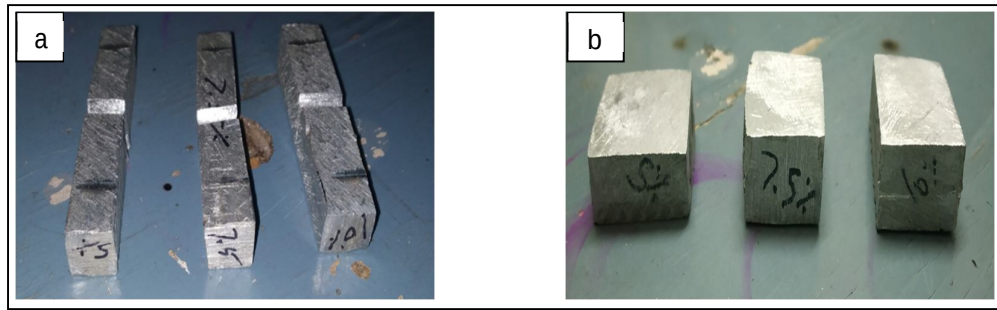


Fig. 3. Prepared test specimens (a) impact test (b) hardness test

3.2 Mechanical test results

The impact test and hardness test were performed using the Charpy impact test and Rockwell hardness test machine. The Rockwell scale is a hardness scale based on material surface indentation. The Rockwell test compares the depth of penetration of an indenter under a large load to the depth of penetration made by a preload to assess hardness. The tensile strength of testing materials is proportional to their indentation hardness. This crucial relationship allows for cost-effective nondestructive testing of bulk metal deliveries using lightweight, even portable equipment like hand-held Rockwell hardness testers. Table 2 shows the results of the impact testing and hardness testing.

Table 2. Mechanical test results

S. No.	Impact Test		Hardness test			
	Composites	Strength (J)	Run 1	Run 2	Run 3	Avg.
1	Al + 5% SiC	17	40.59	38.32	38.94	39.28
2	Al + 7.5% SiC	22	41.25	42.92	42.57	42.24
3	Al + 10% SiC	26	43.24	44.91	43.29	43.48

From the test results, it was observed that composite material has more strength than conventional material. It was also observed that the strength also increases with the increase of % of SiC.

4. DESIGN AND FABRICATION OF SPUR GEAR

The design of a product is an essential task before its actual manufacturing. Module, pressure angle, root radius, tooth thickness, and number of teeth are the parameters that describe gear. The finite element approach excels at using design information to create an accurate model. As a result, a pre-processor method, such as Pro/Engineer, that builds out the geometry required for finite element analysis can be employed to save modelling time. Pro/Engineer has the ability to create three-dimensional gear models. Figure 4 shows the numerical results of the design spur gears. Gear deflection and pressure play major role in gear failure. In this analysis, the force applied on the gear was taken as 10k N.

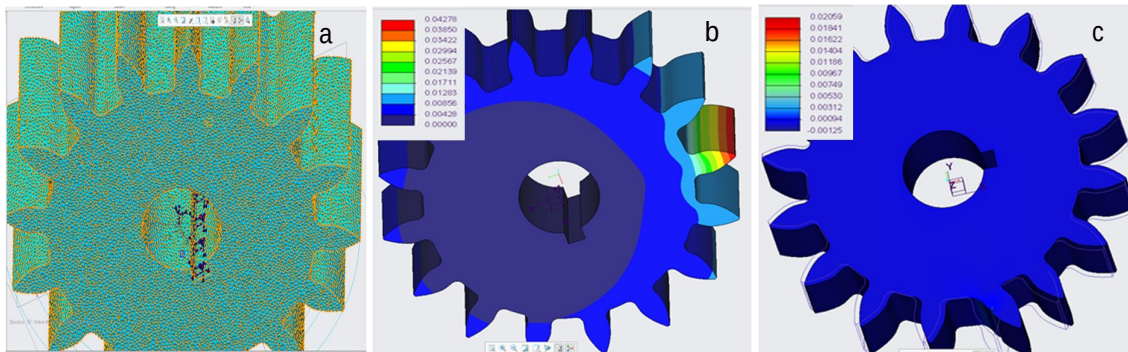


Fig. 4. Design and analysis results of spur gear (a) mesh, (b) deflection, (c) stress

5. FABRICATION OF GEAR

Different machines were utilized to fabricate the composite spur gear to get the required shape size, such as a Power cut machine, lathe machine, vertical milling machine, horizontal milling machine, file. The initial condition to the final product, i.e., the spur gear, is shown in fig. 5. In this spur gear, 16 teeth were made using the milling machine.

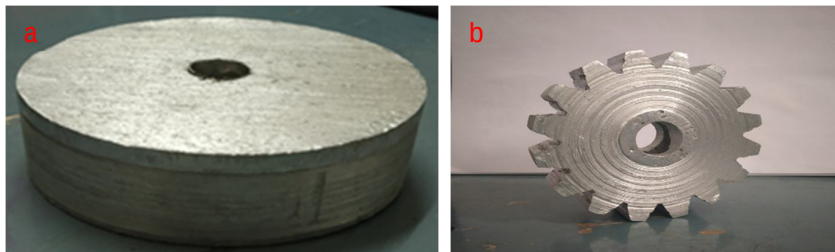


Fig. 5. Fabricated Al6063+SiC Metal Matrix Composite spur gear, (a) Block, (b) Spur gear.

6. CONCLUSION

In this study, Al6063+SiC Metal Matrix Composite was prepared using a stir casting process. The prepared metal matrix composites' mechanical testing was performed. The mechanical testing results showed that Al6063+SiC Metal Matrix Composite has better properties than conventional spur gear metals. The hardness and impact strength of material increase with increasing the % of SiC in composite material. The composite with 10% SiC was utilized for the numerical analysis and fabrication of spur gear.

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